GRC Environmental Programs Manual

Chapter 29 – Radiation Protection for Radiation-Generating Equipment

NOTE: The current version of this Chapter is maintained and approved by the Environmental Management Office (EMO). The revision date for this chapter is October 2004. If you are referencing paper copies, please verify that it is the most current version before use. The current version is maintained on the Glenn Research Center intranet at http://smad-ext.grc.nasa.gov/emo/pub/epm/epm-contents.pdf. Approved by: EMO Chief, Michael Blotzer {mailto: Michael.J.Blotzer@nasa.gov}

PURPOSE

This chapter describes the policies, procedures, and radiation protection requirements for the procurement and use of radiation-generating (a.k.a x-ray-producing) equipment. Radiation-generating equipment are devices which produce ionizing radiation without the use of radioactive material (i.e., nuclear sources).

APPLICABILITY

The provisions of this chapter are applicable to civil servants, support-service contractors (SSC) and construction contractors at NASA Glenn Research Center's Lewis Field and Plum Brook Station.

DEFINITIONS

Analytical Radiation-Generating Equipment
A group of system of components which produce ionizing radiation as either a primary or a secondary result and is used to determine or alter the properties of materials being measured or analyzed. Analytical Radiation-Generating Equipment includes, but is not limited to, gauging units, electron microscopes, x-ray diffraction, x-ray fluorescence, and spectrometer devices. Many of these systems use x-rays to determine or examine the composition or microstructure of materials.

ALARA – As Low As Reasonably Achievable
Making a reasonable effort to maintain exposures to radiation as far below the dose limits as is practical (1) consistent with the purpose for which the activity is undertaken, (2) taking into account factors such as available technology and the economics of improvements with respect to their benefits, and (3) in relation to the performance of such activities for the public interest.

Computed Tomography, or "CT"
An imaging procedure that uses multiply x-ray transmission measurements and a computer program to generate tomographic images of a material (or patient).

Diagnostic Radiation-Generating Equipment
X-ray machines designed for irradiation of any part of the human body or animal for the purpose of diagnosis or visualization.

Diffraction
An analytical process which reflects/deflects an x-ray beam, which is incident on a target material

Dose, Absorbed
The amount of ionizing radiation energy absorbed in matter, including human tissue. The units of absorbed dose are the rad and the gray (Gy).

Dose, Equivalent
The dose quantity used for radiation-protection purposes that takes into account the different effects observed in tissue for different types of radiation giving the same *absorbed dose*.

Dosimetry
Equipment used for measuring and registering accumulated exposure to ionizing radiation. For the purposes of this chapter, these devices include personal monitoring devices such as thermo-luminescent detectors (TLD), optically-stimulated luminescent detectors (OSL), self-reading dosimeters (SRD), or film badges.

Fluorescence (Glowing)
An analytical process that uses x-ray beam absorption to cause target materials to emit visible light

High Radiation Area
An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 100 mrem in any one hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Industrial Radiography Equipment
A device using ionizing radiation (from either a sealed nuclear source or an x-ray unit) to examine (via real-time imaging or photographic film) the macroscopic structures of material by nondestructive methods.

Ionizing Radiation
Any radiation (particle or wave) capable of displacing electrons from atoms or molecules, thereby producing ionx. Examples: alpha, beta, gamma, x-rays, neutrons, high-speed electrons, protons and other atomic particles

Irradiation Equipment
Radiation-generating equipment used to alter the chemical, biological, or physical properties of materials or to sterilize materials. Irradiation equipment includes, but is not limited to, electron beam processors, electron beam welders, electron beam coaters, and cabinet irradiators.

Open Beam
An analytical radiation-generating equipment in which an individual could place any part of their body in the primary beam during operation.

Permanent Radiographic Installation
A shielded installation or structure designed or intended for radiography an in which radiography is regularly performed.

Radiation Area
An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 5 mrem in any one hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Rem
The unit used for *dose equivalent*. The *dose equivalent* in *rem* is equal to the *absorbed dose* in *rad* multiplied by the quality factor. Also, 1 rem = 0.01 sievert.

Restricted Area
An area, access to which is limited for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials.

Temporary Job Site
Any location (i.e. in the field) where industrial radiography is performed other that “permanent radiographic installations” specifically designed for such activities.

Therapeutic Radiation-Generating Equipment
X-ray or electron-producing machines designed and used for external beam radiation therapy.

BACKGROUND

Radioactive materials (RAM) and radiation-generating equipment (RGE) are used safely throughout the industrial, medical and research communities. When not properly controlled, however, ionizing radiation can present a hazard to individual users and/or others in the immediate environment. Historical and scientific data tell us that very high doses of ionizing radiation received over a short period ("acute exposure") and high exposures received over a long period (i.e., "chronic exposure") present various health hazards to people. The Glenn Radiation Protection Programs establish the policies, procedures and responsibilities necessary for the safe operation and handling of radioactive materials and radiation-generating equipment.

POLICY

The Glenn Research Centers Radiation Protection Programs for Radioactive Materials and for Radiation-Generating Equipment are designed to maintain and preserve the health of our employees by eliminating unnecessary and accidental exposures and minimizing necessary exposures to ionizing radiation. Exposures to ionizing radiation are to be kept As Low As Reasonably Achievable (ALARA).

All uses of radioactive materials or radiation-generating equipment are approved by the Radiation Safety Officer (RSO) via either the materials application process or the safety permit process. Representatives of the Environmental Management Office periodically assess the ionizing radiation hazards of the activities. In addition, the RSO is responsible for ensuring that an annual audit of the effectiveness of the Radiation Safety Program is conducted. In addition to protecting our workers, the requirements and conditions of the Glenn Research Center's Radiation Protection Program for Radiation-Generating Equipment demonstrate compliance with applicable regulations of the Occupational Safety and Health Administration (OSHA).

RESPONSIBILITIES

Equipment User – to satisfy training and other requirements of this chapter in addition to working in a safe manner in accordance with established procedures for their particular radiation-generating equipment.

Equipment User's Supervisor – to ensure operators of radiation-generating equipment follow established procedures and meet requirements specified in this chapter and any applicable safety permits.

Radiation Safety Officer (RSO) – to ensure activities involving radiation-generating equipment are conducted in accordance with NASA and OSHA requirements. See Appendix A for detailed responsibilities.

Safety Committee Chairperson – to lead safety permit evaluations and provide guidance to the safety permit requester on how to satisfy permit conditions. In cases involving radiation-generating equipment, the Safety Committee Chairperson will include the RSO as an ad-hoc member of their evaluation committee.

GRC Medical Services – to provide medical surveillance and post-exposure evaluation, as well as follow-up actions, in accordance with NPR 1800.1. Records from such examinations/evaluations are to be retained for at least 30 years. Results of examinations are to be discussed with employees as needed. Also, Medical Services is responsible for having the annual quality assurance inspection of the diagnostic x-ray facility is completed and deficient items are corrected.

Glenn Environmental Management Office (EMO) Chief – to provide support to the radiation safety officer in the performance of their duties.

Glenn Safety Office (GSO) Chief – to provide support to the safety committee chairpersons in the performance of their duties.

REQUIREMENTS

Training & Qualifications

Analytical Radiation-Generating Equipment

NASA civil servants and SSC using analytical radiation-generating equipment at GRC must receive radiation safety training designated by the radiation safety officer. These individuals must also be trained to operate their specific equipment per any training and qualification criteria identified within the applicable BMS documents for said activity as well as the relevant safety permit.

Industrial Radiography

NASA civil servants and SSC performing radiography operations in a permanent radiographic installation must receive radiation safety training designated by the radiation safety officer. These individuals must also be trained to operate the radiation-generating equipment involved per the training and qualification criteria identified in the applicable BMS documents for said activity as well as the relevant safety permit. ASNT training (or its equivalent) and certification are highly recommended for individuals performing radiography in a permanent facility.

NASA civil servants and SSC conducting radiography activities at temporary job sites (i.e. in the "field") and their assistants must receive radiation safety training designated by the radiation safety officer. In addition, the radiographer must be trained to operate the radiation-generating equipment involved per the training and qualification criteria identified in the applicable BMS documents for said activity as well as the relevant safety permit. ASNT training (or its equivalent) is required for the "radiographer"performing field shots.

Construction contractors conducting radiography activities at temporary job sites (i.e., in the "field") and their assistants must satisfy training and work experience requirements specified by the Ohio Department of Health in Chapter 3701:1-66 of the Ohio Administrative Code. Records of such training and certification must be available to the Glenn Research Center's RSO upon request.

Medical Uses of Radiation-Generating Equipment

Operators of the medical x-ray machine must be a graduate of an American Medical Association-accredited school of radiologic technology. They must be registered with the American Registry of Radiologic Technologists (ARRT) and remain in good standing with this organization by satisfying continuing education requirements of the organization. The required training includes 24 continuing education units (CEUs) every two year with 6 of the CEUs in the Radiation Safety area. The Radiologic Technologists (RTs) must also be licensed by the state in which they practice.

Other Radiation-Generating Equipment

Operators of the mailroom x-ray machine must receive radiation safety training specified by the radiation safety officer. These individuals must also be trained to operate the radiation-generating equipment involved per the manufacturer's training specifications. Local criterion for operator qualification may also be applicable.

Medical Surveillance

Radiation medical examinations are conducted in accordance with the requirements set forth in NASA Procedural Requirements (NPR) 1800.1, NASA Occupational Health Program Procedures. Examination categories include pre-placement examinations, periodic re-examinations, situational examinations, and termination examinations. Inclusion is this program is required for employees receiving routine exposure to ionizing radiation in doses above 0.5 rem/year or 0.125 rem/quarter. Currently, no such exposures are expected from GRC personnel. Additionally, a situational examination may be appropriate for accidental exposures to potentially high doses of radiation or if a biological uptake (inhalation or ingestion) of a significant amount radioactive material is suspected.

Dosimetry (see Appendix B for additional guidelines)

The use of personal dosimetry to estimate external radiation exposure will be required for certain activities involving radiation-generating equipment. For some operations, the energy of the x-rays produced is so low that the associated hazard is negligible or possibly not measurable. The RSO will identify when and what type of dosimetry is required. At a minimum, the RSO should assign personal dosimetry to individuals working with RGE who are likely to receive an annual dose in excess of ten percent of their annual allowable limit. In practice, workers are typically assigned to use dosimetry at much lower exposure levels.

- Industrial Radiography in the Field: The radiographer and their assistant(s) are required to wear their whole body dosimeters in addition to self-reading dosimeters during field radiography activities

- Industrial Radiography at Permanent, Designated Facility: Individuals are required to wear their whole body dosimeter during such activities.

- Diagnostic Radiation-Generating Equipment (i.e., Medical X-ray Unit): Operators of such equipment will wear whole-body dosimetry during such activities.

- Analytical Radiation-Generating Equipment: Dosimetry requirements vary for this group of equipment; some require no radiation monitoring while others require whole body and/or ring dosimeters. Again, the RSO determines when and what type of dosimetry is required.

- Other Radiation-Generating Equipment: Dosimetry is not required for operator of the mailroom x-ray machine.

The following dose limits apply to individuals at the Glenn Research Center:

Occupational Annual Dose Limits
- WHOLE BODY: 15 Rem
- LENS OF EYE: 15 Rem
- EXTREMITIES, SPECIFIC ORGANS: 50 Rem

Gestation Period Dose Limit to Unborn Fetus of "Declared Pregnant" Radiation Worker
- WHOLE BODY: 0.5 Rem

Members of the Public Annual Dose Limit (due to occupational radiation sources)
- WHOLE BODY: 0.1 Rem

In practice, worker doses at the Glenn Research Center have historically been well below the stated limits. Should a worker's dose for a recording period appear unexpectedly high or, at a minimum, reach ten percent of the prorated allowable dose for that recording period, the RSO would initiate an investigation into the cause of the individual's dosimetry results.

Employees who participate in the dosimetry program will receive an annual report summarizing their radiation exposure data. Also, participants can, at any time, make such a request. In addition, former employees can request a dose history for their time at GRC, which must be satisfied within a specified time frame.

Radiation Surveys of Equipment/Facilities

Radiation surveys of radiation-generating equipment and facilities are used to determine if the equipment operating properly and if associated controls are adequate. If possible, surveys conditions should be established that represent a plausible, "worst-case" exposure scenario. (i.e., operation at higher-than-normal voltage/current, lengthening the exposure period, redirecting the beam path, etc.) Surveys will be conducted using energy-appropriate radiation survey meters. The RSO may, in certain situations, determine that a radiation surveys is not necessary based upon the exposure scenario (i.e. photon energy, shielding, etc). Surveys will be documented using the general "GRC

Radiological Survey Form" in conjunction with the more specific "Radiation-Generating Equipment Inspection and Survey Form."

Typically, surveys are performed upon installation, if the equipment is moved, and on a periodic basis per the schedule below:

- Biennially: analytical radiation-generating equipment
- Annually: all other radiation-generating equipment except for "analytical-" and "field industrial radiography"
- Other: field industrial radiography activities are monitored real-time with survey instruments by the radiographer, his assistant(s) and possibly health physics/EMO staff. No specific "survey" documentation is generated as the surveyor should be positioned at a location where the radiation level averages less than 2 millirem/hour.

Quality Assurance Inspection of Medical X-ray Facility

An annual inspection and performance evaluation shall be conducted for the diagnostic x-ray facility found within Medical Services. The review criteria will be provided by NASA headquarters in NPR 1800.1 or other official guidance. Portions of the inspection shall be performed by a qualified radiological physicist consultant. Other checks can be performed by the medical center and EMO staff. Medical Services and the Radiation Safety Officer should maintain copies of these inspection results.

Industrial Radiography using Radiation-Generating Equipment at a Temporary Job-Site (i.e., "field radiography")

Portable x-ray units are commonly used to perform imaging of equipment/structures/piping that can't be moved to an x-ray facility following repairs or modifications. Typical target materials here at GRC include aircraft fuselage, flight hardware or "thinner" facility piping systems. Because these "field" radiography activities are conducted in environments with limited controls, special procedures are needed to minimize potential hazards to the workers involved as well as the general work population. For activities performed by NASA civil servants or SSC's, these procedures would be contained in the safety permit for the activity. Since there are a great variety of potential field locations, these procedures can be thought to describe the safety philosophy and general guidelines for performing radiography shots in the field.

When such activities are being performed by external contractors, their written health and safety plan (HASP) should describe, in detail, how they will perform their work and manage/control the hazard. The construction safety process and use of the "Health and Safety Plan" is described in Chapter 17 of the Glenn Safety Manual. Contractor's HASPs are approved by Glenn Safety Office and Environmental Management Office personnel. In cases where the work task involves industrial radiography, the facility RSO will also approve the HASP.

Field radiography requirements are established on a case-by-case basis. Typical requirements can include performing the activity off-hours or on the weekend, evacuating areas, barricading and monitoring the work area, and communicating / coordinating such activities with interested parties. In all cases, the Radiation Safety Officer, must be notified of the specific time and place of the field radiographic activity.

Calibration and Maintenance of Portable Radiographic Units

Portable x-ray units used for field industrial radiography operations will be calibrated annually in accordance with manufacturer's guidelines. Records of this calibration and other maintenance performed on these units will be maintained by the radiographer and will be made available to the RSO upon their request.

Safety Permits

GSO's safety permit process is used as a vehicle for assessing and addressing potential health and safety hazards associating with activities at the Glenn Research Center. The radiation safety officer will assist area safety committees in determining requirements, controls, and conditions for a safety permit involving the use of radiation-generating equipment. Typical permit conditions would include training, posting/labeling, the use of radiation dosimetry, periodic radiation surveys, and written procedures.

Area Postings/Controls and Container Labels

Restricted and "radiation" areas shall be marked clearly with signs as designated by the RSO. The signage should also indicate any special requirements pertaining to the particular area. In addition, labels are required at the point of radiation emission and also on the equipment which controls the production of the x-ray beam.

RECORDS (maintained by the RSO or HP unless otherwise noted)

- Annual Maintenance & Calibration for Portable Radiographic X-Ray Units (GRC Radiographer)
- Diagnostic X-Ray Facility Inspections & Quality Assurance Surveys (Medical Services)
- GRC Radiographical Survey Form
- Radiation-Generating Equipment Inspection and Survey Form
- Calibration records of survey instrumentation.
- Radiation Dosimetry Reports and Records

REFERENCES

- U.S. Occupational Safety and Health Administration – 29 CFR 1910.1096 – Ionizing Radiation
- U.S. Food & Drug Administration – 21 CFR 1020 – Performance Standards for Ionizing Radiation Emitting Products
- NASA Procedural Requirement, NPR 1800.1 NASA Occupational Health Program Procedures

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Appendix A
Radiation Safety Officer Responsibilities

The RSO is appointed by the Director to implement the radiation protection programs at the Glenn Research Center (GRC). The RSO's responsibilities include the following:

1. Administer and coordinate the radiation protection programs for all activities involving radioactive materials and ionizing radiation-generating equipment and to ensure that the programs conform with Nuclear Regulatory Commission (NRC) and Occupational Safety and Health Administration (OSHA) regulations as well as NASA policy.

2. Serve as the RSO for all NRC licenses issued to the GRC and determine compliance with license conditions.

3. Provide health physics services and consultation to personnel at GRC. Such services shall include the following:

    a. Provide, distribute, and maintain personnel radiation monitoring equipment (i.e. dosimetry); assess exposures recorded by such personal monitoring equipment; maintain exposure records.
    b. Coordinate the radioactive waste disposal program; provide, collect, store, and dispose of waste containers; monitor effluent; maintain filter systems; maintain waste disposal records.
    c. Supervise the performance of sealed source leak test; maintain inventories.

4. Control all licensed radionuclides at GRC as follows:

    a. Review and approve all requests for procurement of radioactive material.
    b. Assure that sources are properly represented on the center materials license.
    c. Maintain an inventory of radioactive materials at GRC; conduct physical inventories at least semi-annually to comply with license requirements.
    d. Upon notification of receipt of radioactive material shipment, coordinate package survey(s) and open package in approved area; maintain material receipt records.
    e. Authorize all transfers of radioactive materials between center locations
    f. Approve containers and locations for storage of all radioactive materials.
    g. Package or inspect packaging for all off-site transfers of radioactive material; survey packages; assure compliance with NRC and DOT regulations; maintain shipment records.

5. Conduct or coordinate training programs in radiation safety.

6. Maintain all records related to the radiation protection programs.

7. Terminate any activity involving radioactive material or ionizing radiation that is found to be a threat to health or property.

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Appendix B
Guidelines for Personal Dosimetry

Obtaining Dosimetry

Individuals needing radiation dosimetry are to contact the RSO. After satisfying training requirements and providing needed personal information, the individual will be issued their dosimetry and instructed on its use. New occupational workers are also required to provide the RSO with a record of occupational dose from previous employment. Information such as a new worker's accumulated dose for the current calendar year and any past "special exposures" will allow the RSO to appropriately manage their dose received in their inception year and over their career at the Glenn Research Center

Temporary Need for Dosimetry

Temporary monitoring devices can be issued to transient personnel who may be assigned short-term work in a radiation area. The RSO will evaluate the radiation area and assign monitoring devices as appropriate.

Specification of Dosimetry Type

The need for and type of radiation dosimetry assigned is based upon the characteristics of the ionizing radiation and the type of activity involved. Dosimeters are used to estimate an individual's radiation dose cause by external sources of radiation.

Use of Dosimetry

Whole Body
"Whole body" dosimeters are used to estimate the radiation dose delivered to the head, trunk and thigh area of a worker. This region of the body includes the major organs and blood forming areas that would be more susceptible to chronic radiation exposure effects. The "whole body" badge is to be worn in its holder on the front of an individual's body in between their head and waist.

Self Reading
Self reading dosimeters (SRD) are used to provide a "real time" estimate of an individual's dose to x-rays or gamma rays. SRD's are typically worn in addition to an individual's "whole body badge" when that individual could be involved in an activity involving higher dose rates. The self reading dosimeter is to be worn similarly to the "whole body" badge. SRD's are to be checked by the user periodically during the exposure event to keep tabs on a worker's accumulated exposure. The dose estimated from an SRD is used for guiding actions during an exposure scenario. The SRD dose does not become the individual's official dose of record.

Ring and Extremity Badges
Ring or wrist badges may be specified for activities where a worker's hands come in closer contact to the field of ionizing radiation than their body. Ring badges have higher detection thresholds than whole body badges, and, along those lines, exposure limits for extremities are an order of magnitude greater than whole body limits.

Notify the RSO Immediately

There are certain situations where dosimetry wearers would need to notify the RSO immediately. Users would need to provide a written account detailing the event: who else was involved, when did it occur, what were the radiation characteristics, how long, etc. Situations would include, but are not limited to:

Lost Dosimetry – if you are unable to find your badge following its use for exposure monitoring.
Damaged Dosimetry – if your badge's physical integrity was compromised

Irradiated While Not In Use – if your badge was dropped in an area that subsequently received a high radiation dose
Forgot to Wear a Badge – if you proceeding in performing dosimetry-required activities without being monitored.
Involved in a Potential High Exposure – if you suspect you might have received an acute high dose.

In all but the last of these scenarios, the user would be assisting the RSO in finding a way to estimate the individual's true dose for the exposure scenario. Notification in a potential high dose incident is needed to manage the affected individuals' dose(s).

Additional Guidelines for Dosimetry Users

- Wear your dosimeter as specified for the work being performed
- Know where your dosimeter (s) is at all times
- Use only the dosimeter assigned to you
- Use your assigned dosimeter only at GRC's Lewis Field or Plum Brook Station, and only in the areas for which it was assigned
- Never intentionally irradiate your dosimeter to check the accuracy of the radiation safety process
- If you have a medical procedure requiring the use of a radioactive tracer, contact the RSO and do not wear your dosimeter until the tracer has dissipated
- Consult with the RSO regarding any concerns or questions on the use of dosimetry or the dosimetry program
- Dosimetry reports are on file with the RSO. Program participants receive an annual record of their dose and are advised to keep such records for their personal use.

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Appendix C
Guidance for Construction Contractor Performance of Field X-Ray Radiography

Industrial Radiography

- A copy of the construction contractor's radiography license shall be included with the health and safety plan (HASP) or otherwise provided to the RSO.
- The HASP for the radiography activity must demonstrate specific knowledge about the planned shots, how they will be conducted safely, and what coordination issues might exist (i.e. impact on GRC employees or other construction contractors working in the nearby vicinity.)
- The HASP should include a diagram or map showing the location of the 2 millirem per hour isodose line. Assumptions used in establishing this boundary should be identified in the HASP or its attachments.
- Areas that need to be evacuated during the radiography shots along with how such areas are to be secured must be identified in the HASP. Coordination with other workers may involve working with the appropriate building manager or the construction manager. Industrial radiography is commonly performed on off-shifts or over the weekend.
- Any other necessary special controls to be implemented during radiography activities must be described in the HASP.
- The HASP should list emergency contract numbers for the contractor's RSO and the Glenn RSO (dispatch)
- The radiographer must comply with all conditions of their radiography license. Required records (training, procedures, license, etc.) must be available to GRC personnel when the contractor is on site.